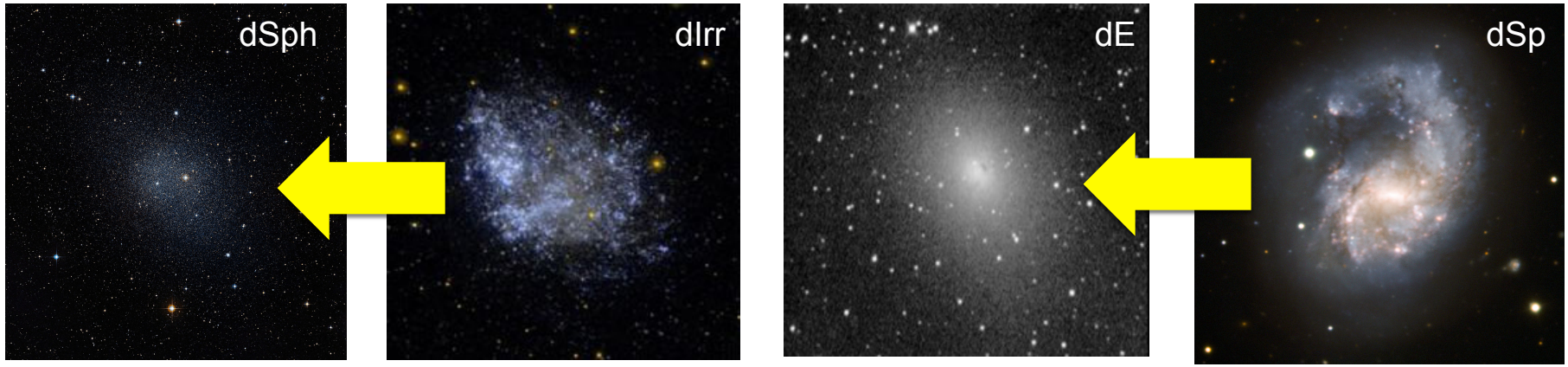
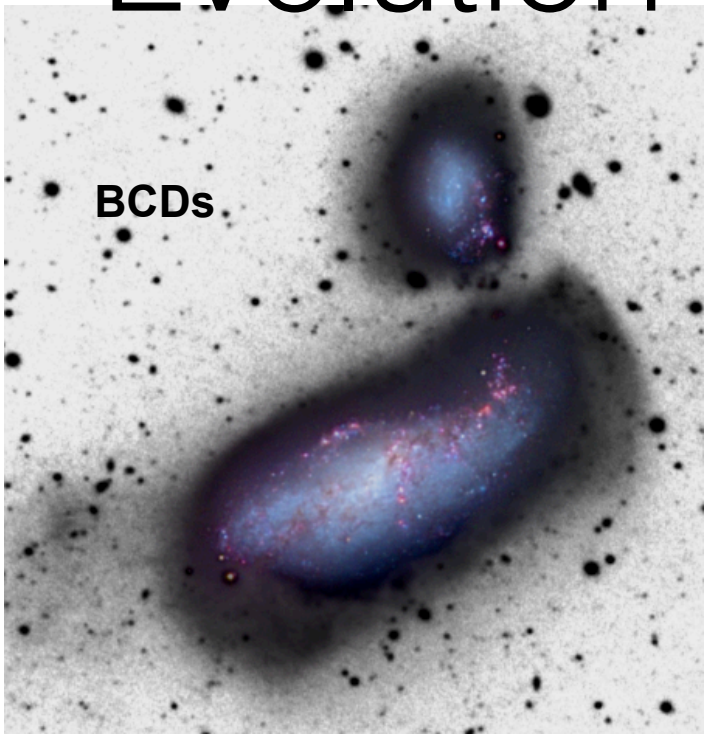


Environment and the Evolution of Dwarf Galaxies



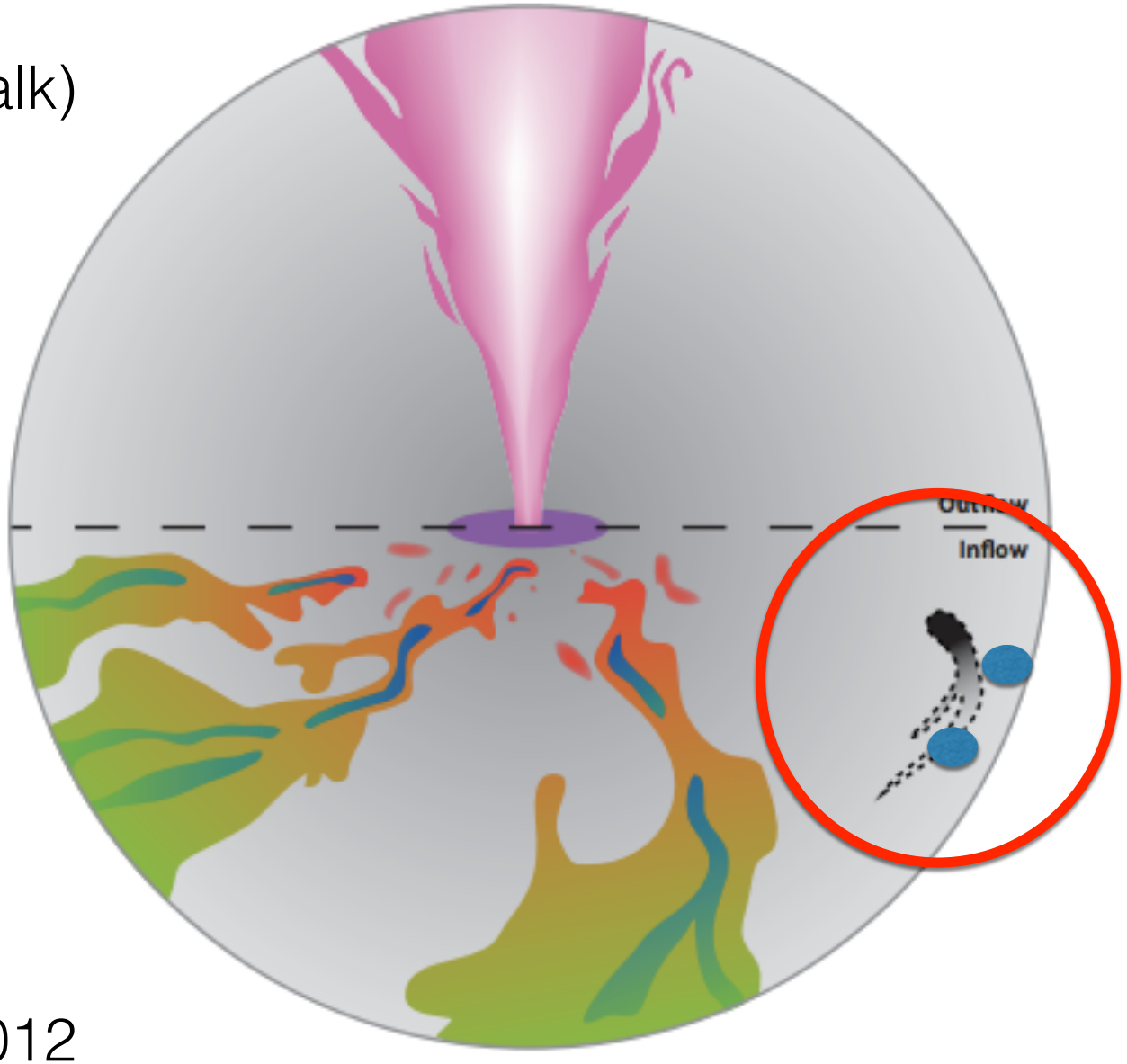
Gurtina Besla
U Arizona

Sarah Pearson, George Privon,
Sabrina Stierwalt

Dave Patton, Mary Putman,
Kelsey Johnson, Nitya Kallivayalil

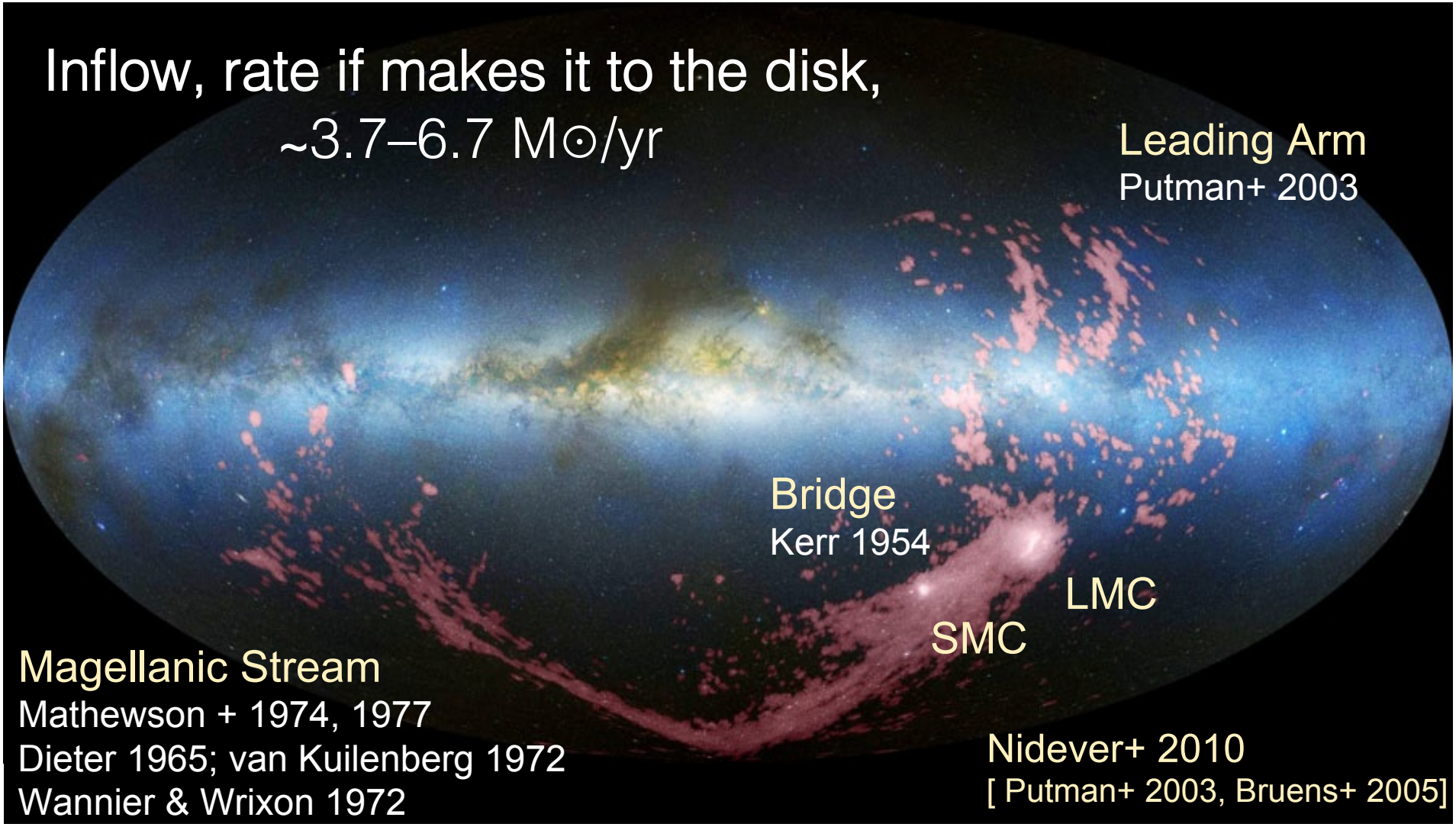
Minor Mergers: Feeding the CGM

(Martin Talk)



Putman+2012

Minor Mergers: Feeding the CGM



$M_{Gas\ outside} \sim 2 \times 10^9\ M_\odot (d/55\ kpc)^2 > 2 \times M_{Gas\ LMC+SMC}$

Fox+ 2014

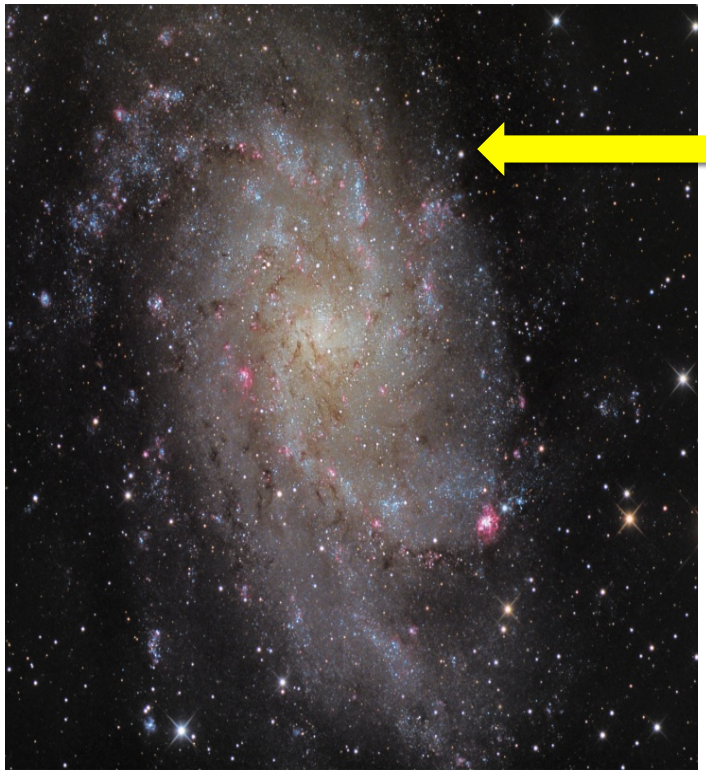
What is a Dwarf Galaxy?

MASS : $\sim 10^5 < M_* < 5 \times 10^9 M_\odot$; $M_V > -19$

ROTATION CURVE : $V_{rot} < 100$ km/s

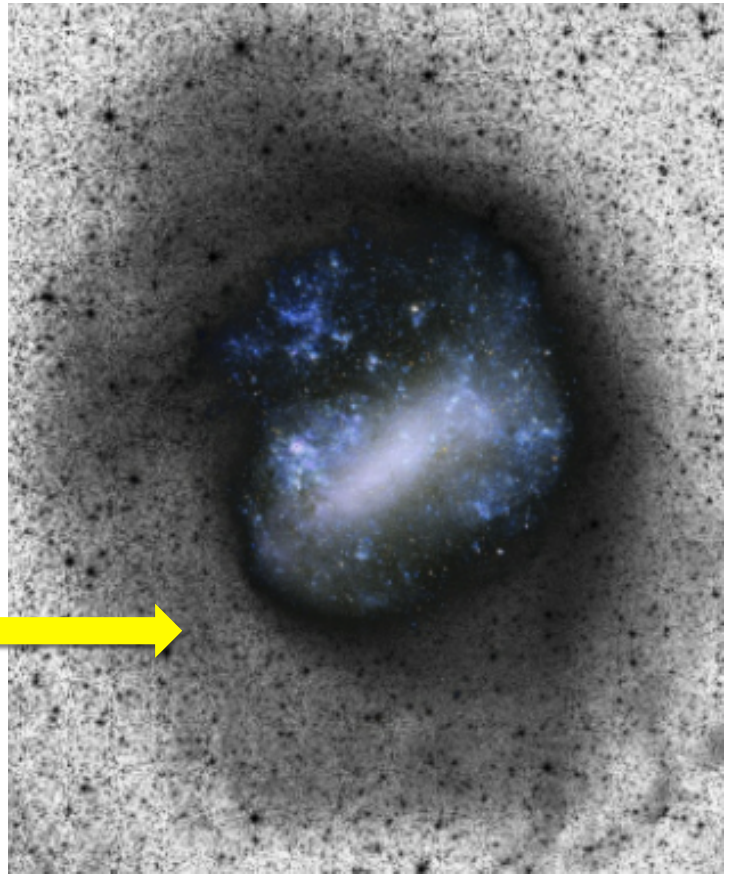
METALLICITY : [Fe/H] $< -0.4 \sim 1/3\ Z_\odot$

Evidence for a dark matter halo



M33 is a satellite, but not a dwarf (Sc)

The LMC is.

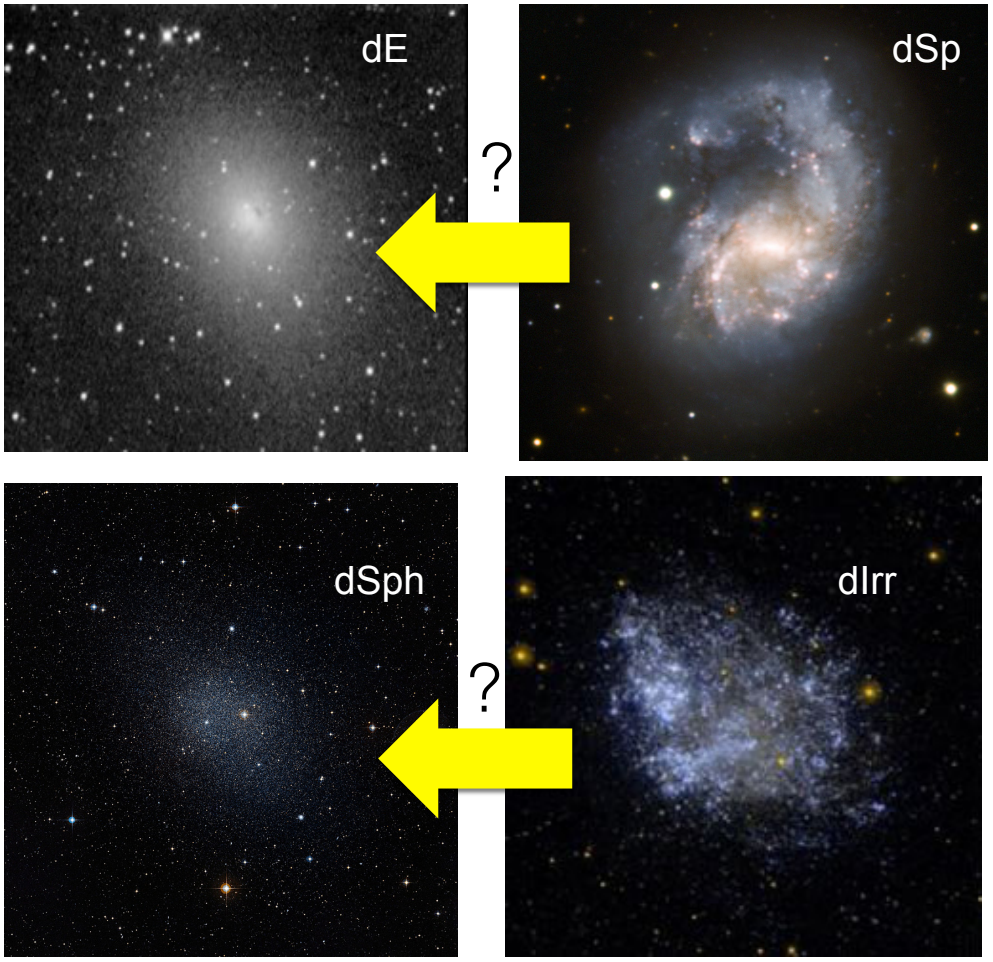


The Dwarf Galaxy Zoo: Quenching & Morphological Change

(Lelli Talk)

No Gas/SF
Spheroids

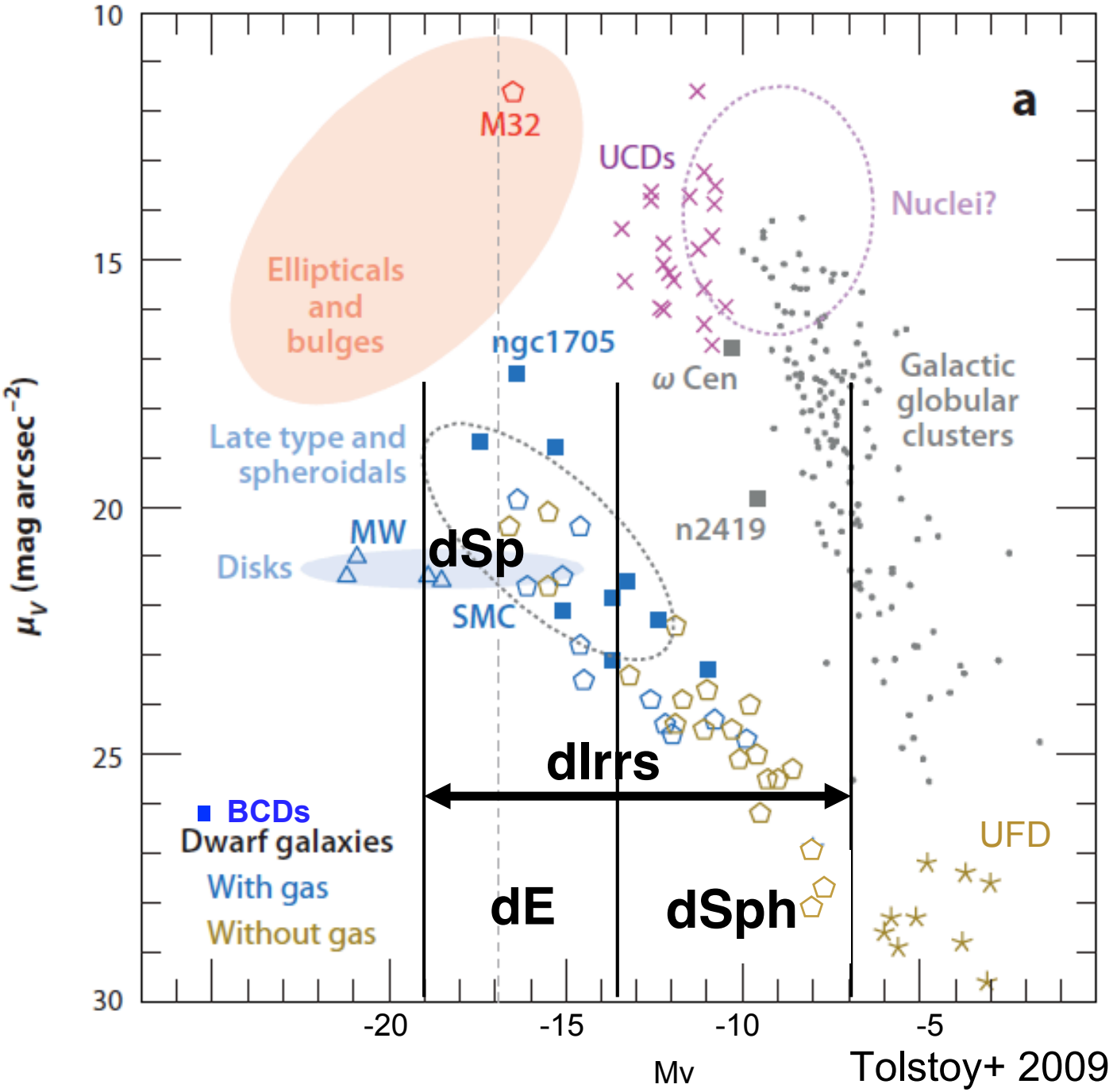
Gas & SF
Disks/Rotation



$5x10^9 > M_* > 10^7\ M_\odot$

$10^7 > M_* > 10^5\ M_\odot$

Below this,
reionization


a
M32
UCDs
Nuclei?
Ellipticals
and
bulges
ngc1705
ω Cen
Galactic
globular
clusters
Late type and
spheroidals
MW
Disks
dSp
n2419
SMC
dIrrs
BCDs
Dwarf galaxies
With gas
Without gas
dE
dSph
UFD
10
15
20
25
30
-20
-15
-10
-5
Mv
μV (mag arcsec−2)
Tolstoy+ 2009

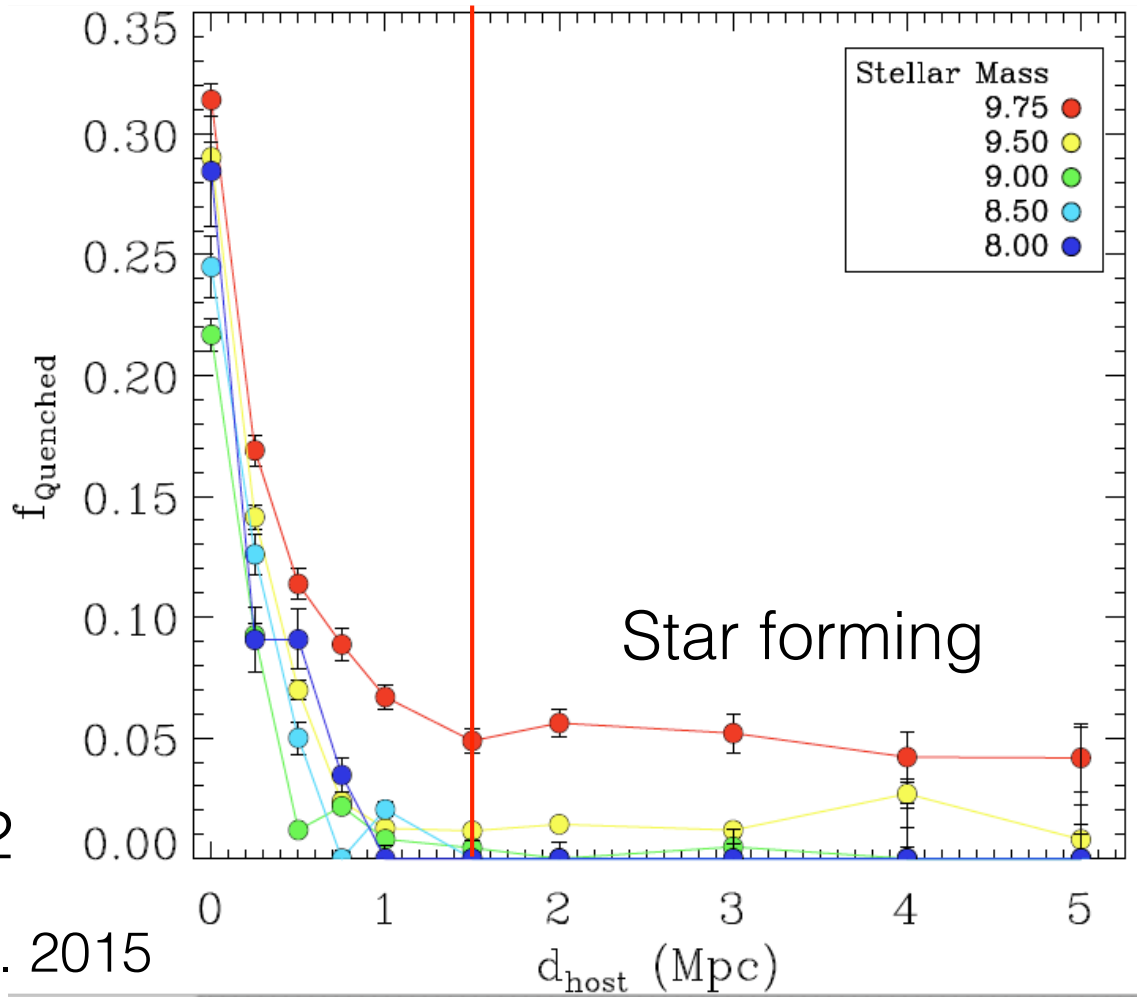
1. How do dwarfs quench?

2. Do dwarf-dwarf interactions/mergers matter ?

Dwarf galaxies are gas rich

UNLESS they are close to a massive galaxy

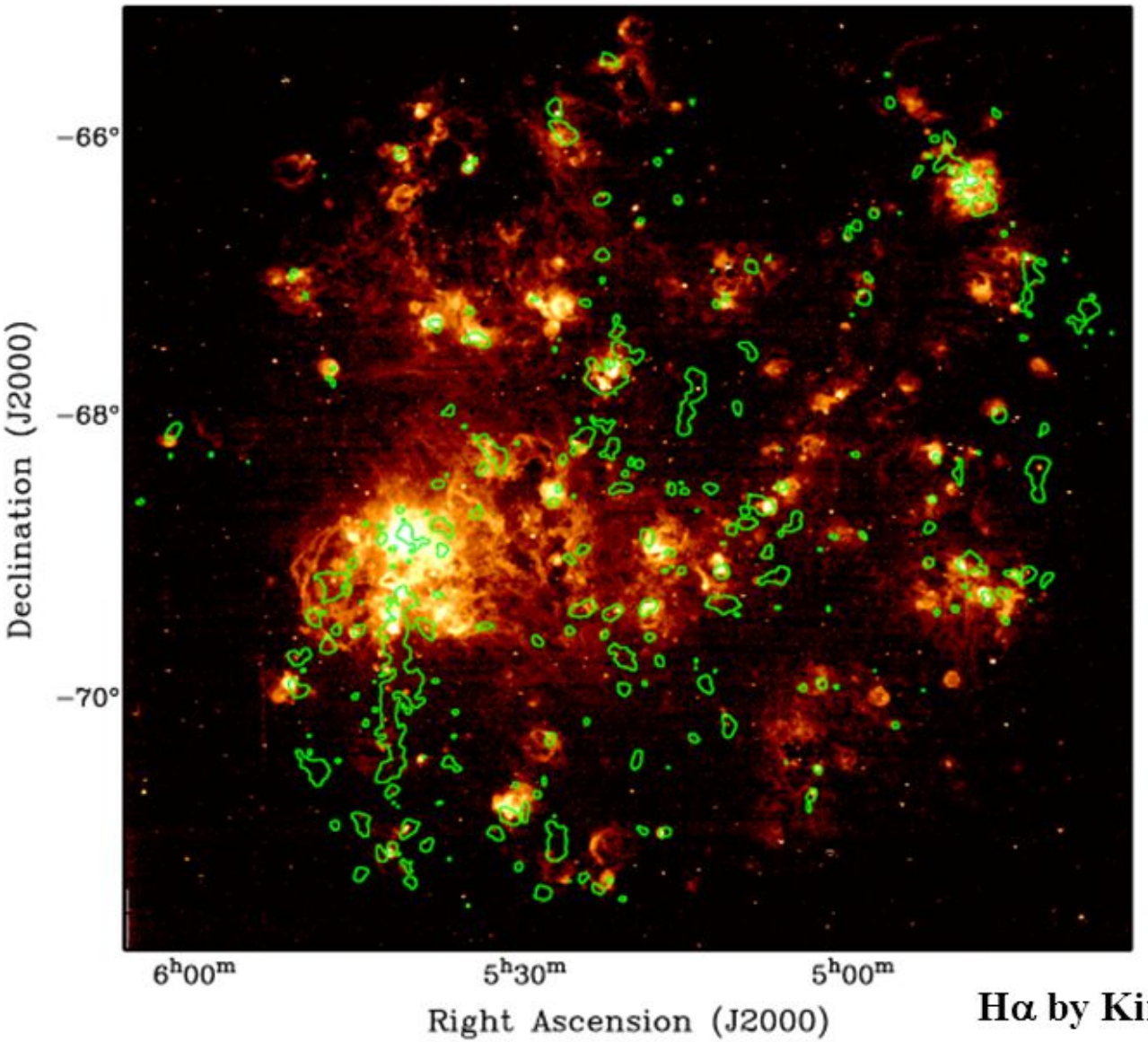
Dwarfs (10^8-10^9 $M_\odot$) DON'T quench via secular processes



Geha+2012

Bradford et al. 2015

LMC: CO and Hα



Most of the molecular gas in the LMC is <u>not forming stars.</u>

Green contour:

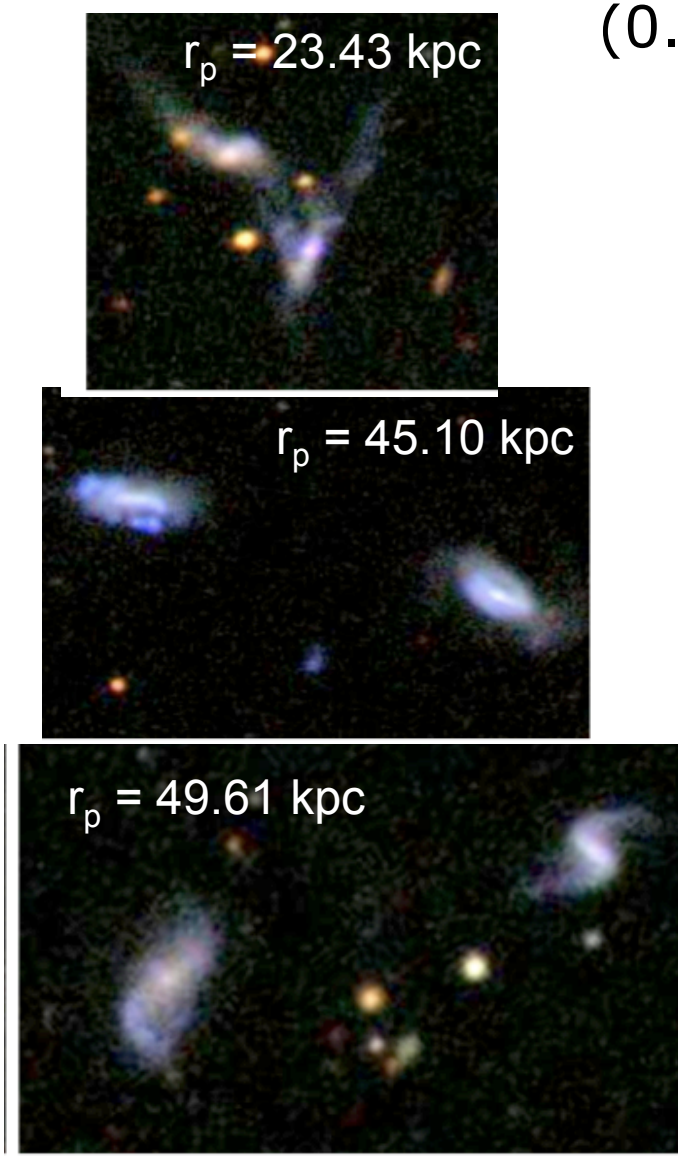
GMCs by NANTEN

Fukui et al. (2008)

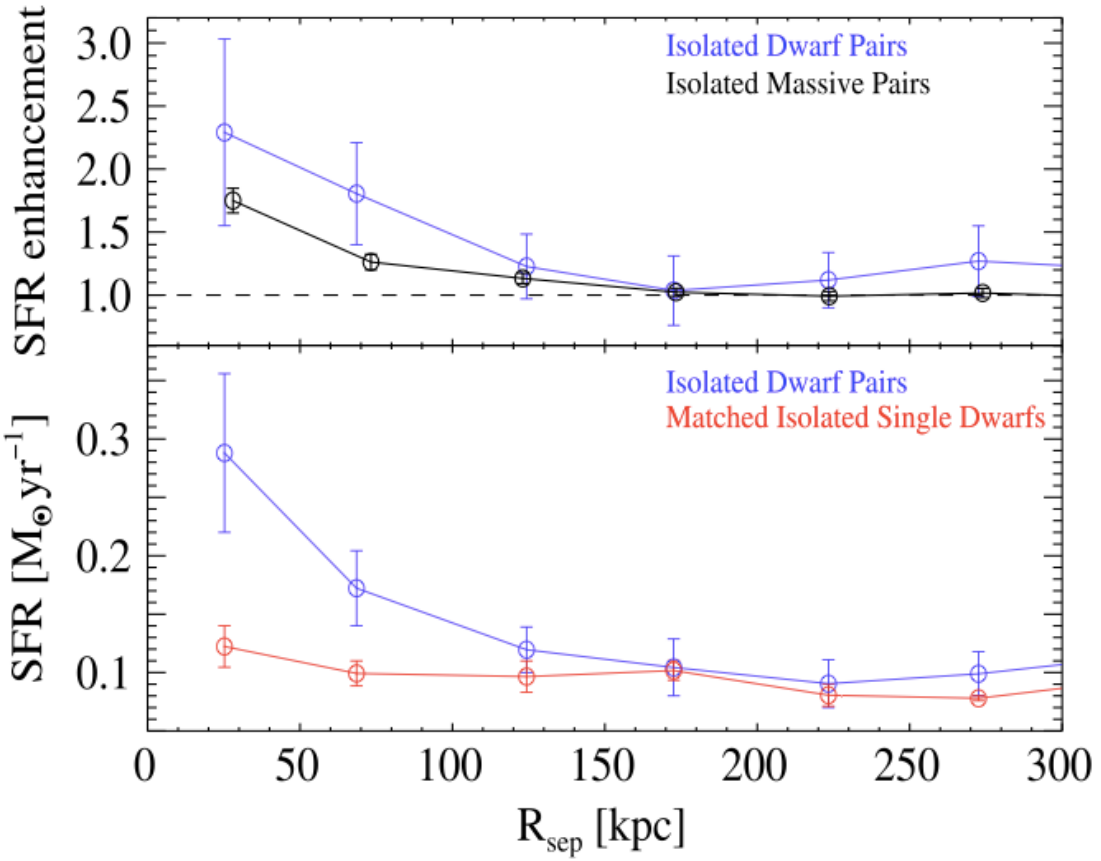
Hα by Kim et al. (1999)

The TiNy Titans (TNT) Survey

Multi-wavelength observations of Dwarf groups found in SDSS
(0.005 < z < 0.07)

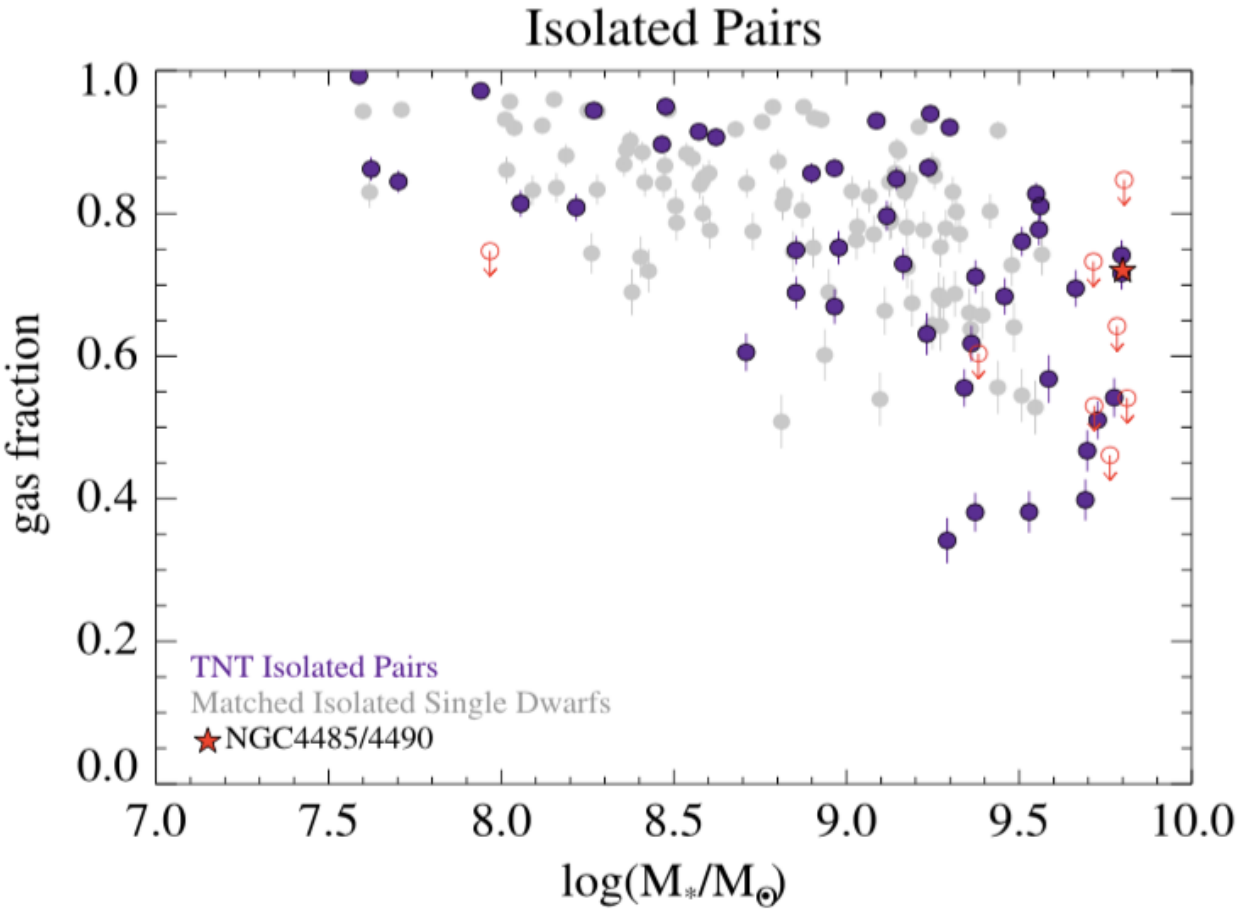


SFRs are augmented in Dwarf Pairs



Stierwalt, Besla+2015

Major Dwarf Mergers can't quench – gas consumption rate is low



Stierwalt, GB+2015

1. So how do dwarfs quench?

NOT : outflows, AGN, mergers, starbursts

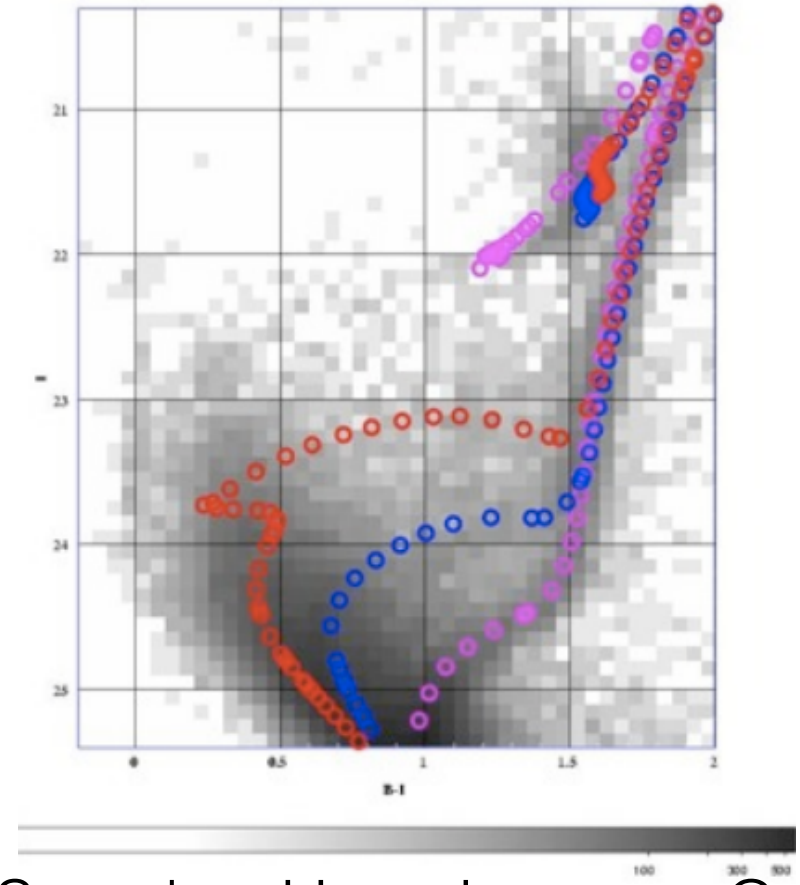
They become satellites of more massive galaxies*

* Dwarfs can also be hosts of smaller dwarfs

SFH of a quenched dwarf: Leo I

$M_* \sim 5 \times 10^6 M_\odot$

SFHs from resolved CMDs

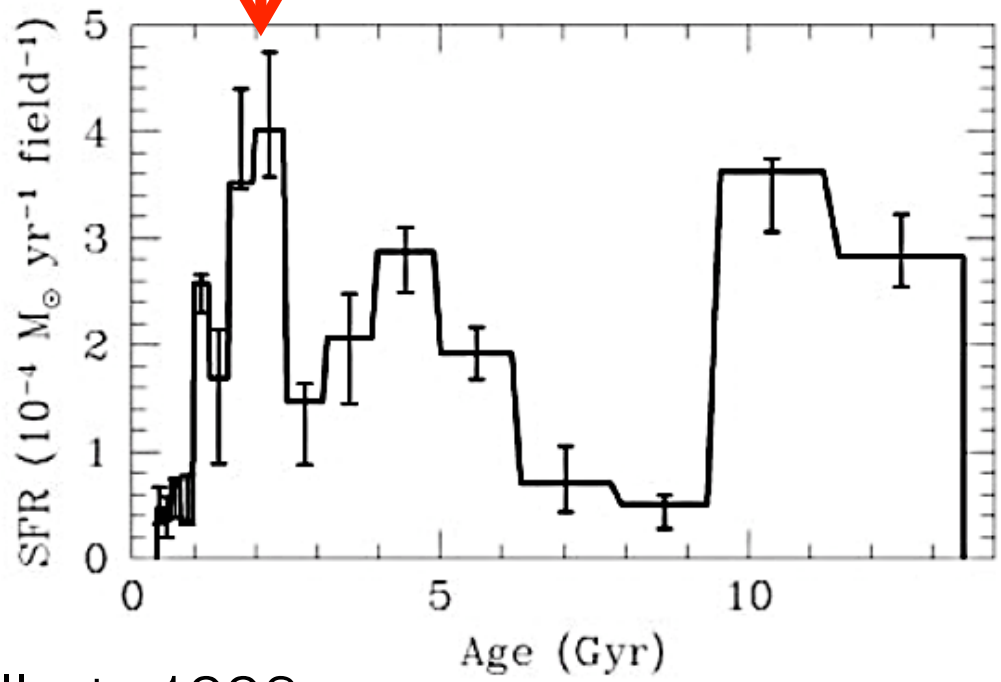


Orbits: HST Proper motions

Accretion by Milky Way

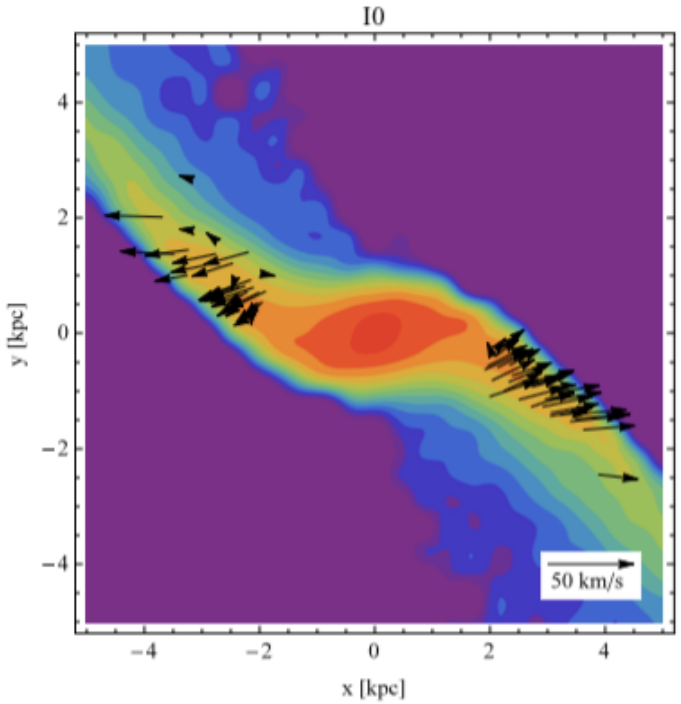
2 Gyr ago (Sohn, GB+2013)

Rapid quenching (Wetzel+2015)



Smecker-Hane in prep, Gallart+1998

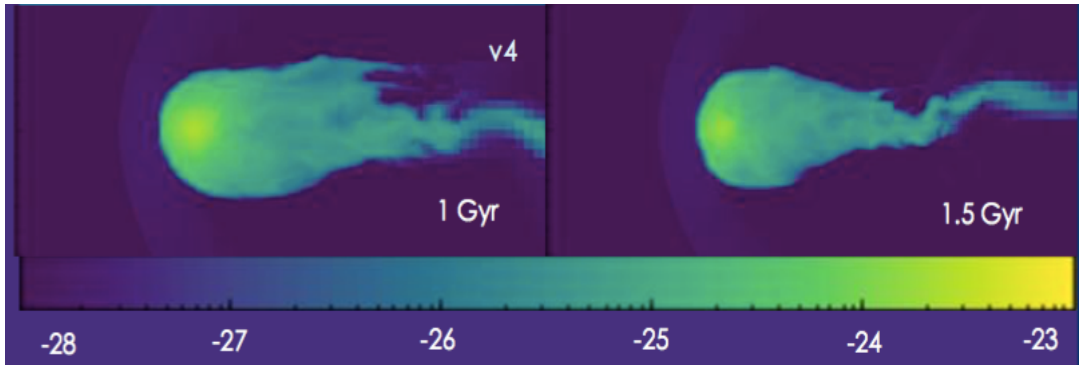
TIDAL STRIPPING
(Beaton Talk)



Lokas+2015

+

RAM PRESSURE STRIPPING
(not always 100% efficient);
Emerick, Fillingham,
Ramos-Martinez posters

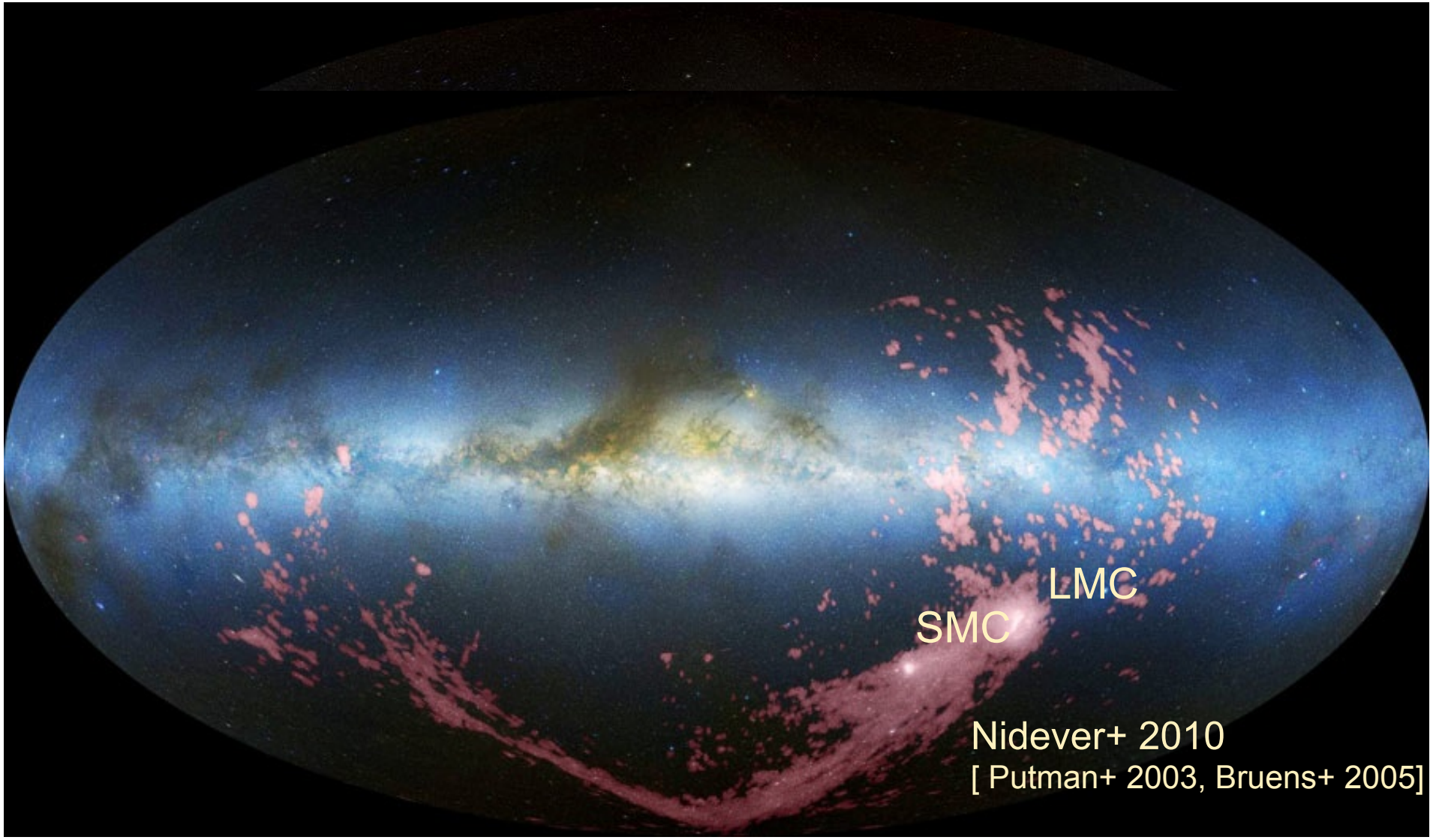


Emerick+ 2016

+

STRANGULATION
(gas supply cut off
Passive SF)

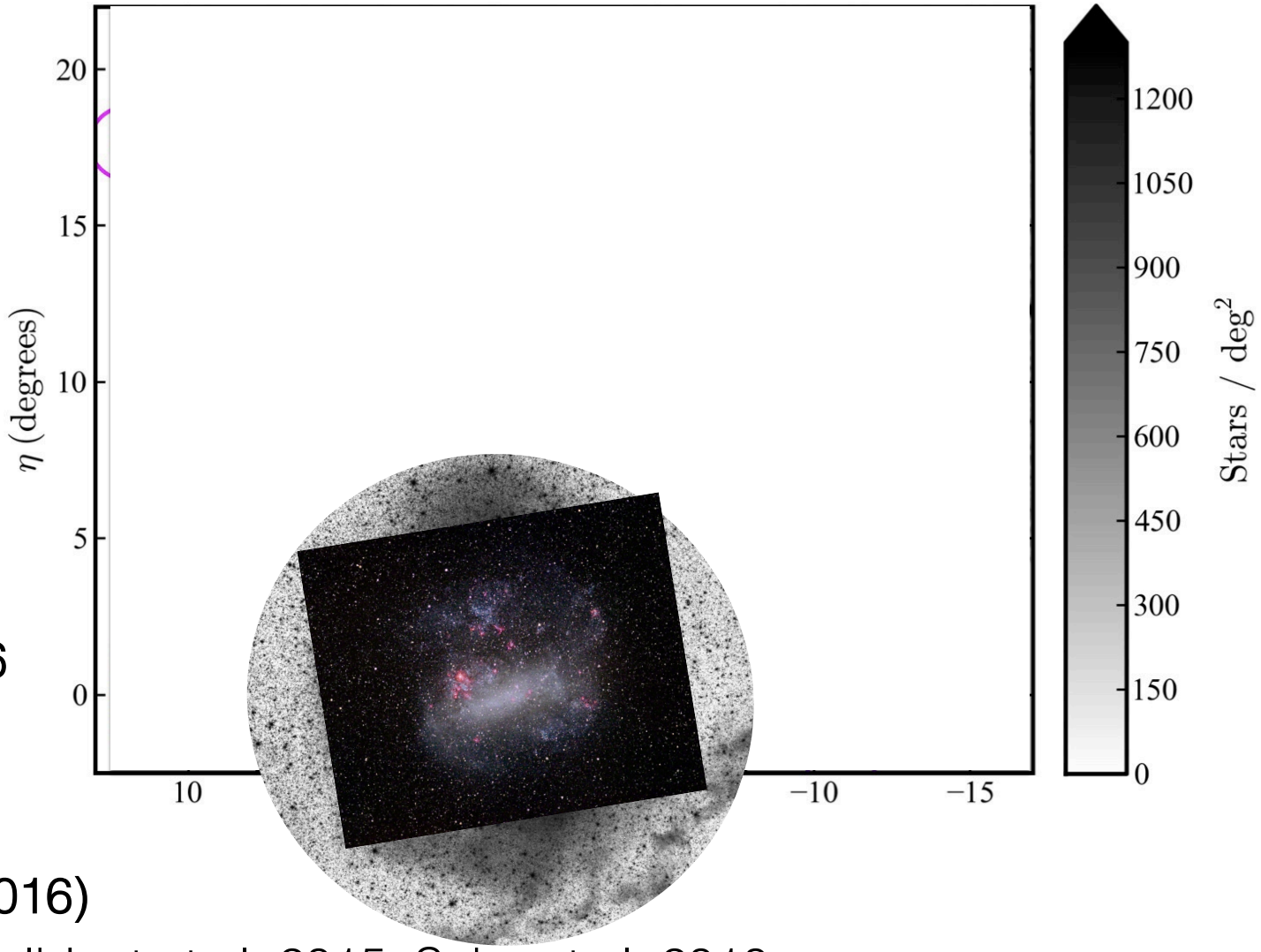
So How Did The Stream Form?



Are Galactic Tides and Ram Pressure Stripping Sufficient?

The LMC Tidal Radius > 18.5 kpc

Milky Way Tides are insufficient to quench



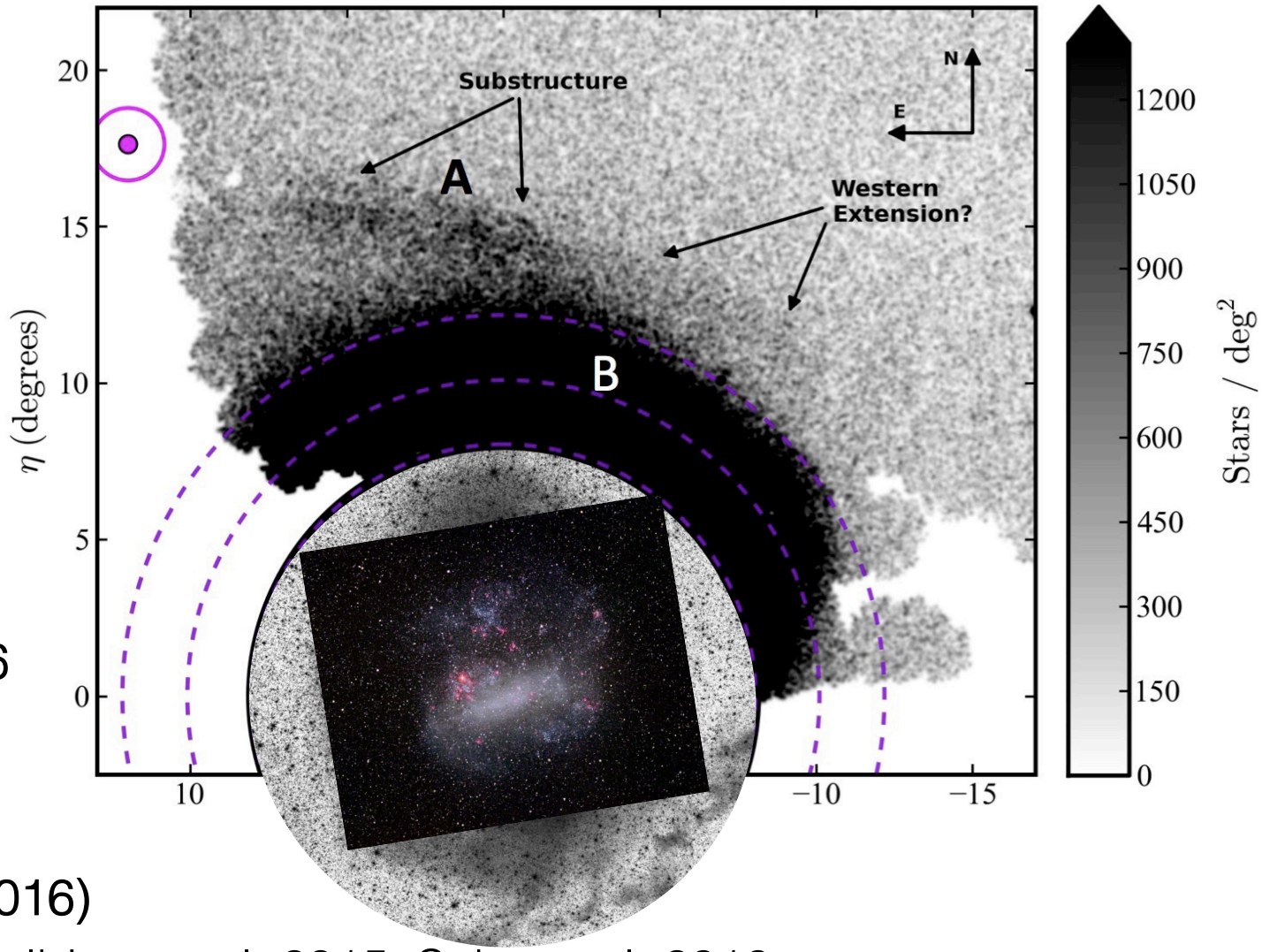
Inner:
Besla+2016

Outer:
DES
(Mackey+2016)

See also: Balbinot et al. 2015; Saha et al. 2010

The LMC Tidal Radius > 18.5 kpc

Milky Way Tides are insufficient to quench



Inner:
Besla+2016

Outer:
DES
(Mackey+2016)

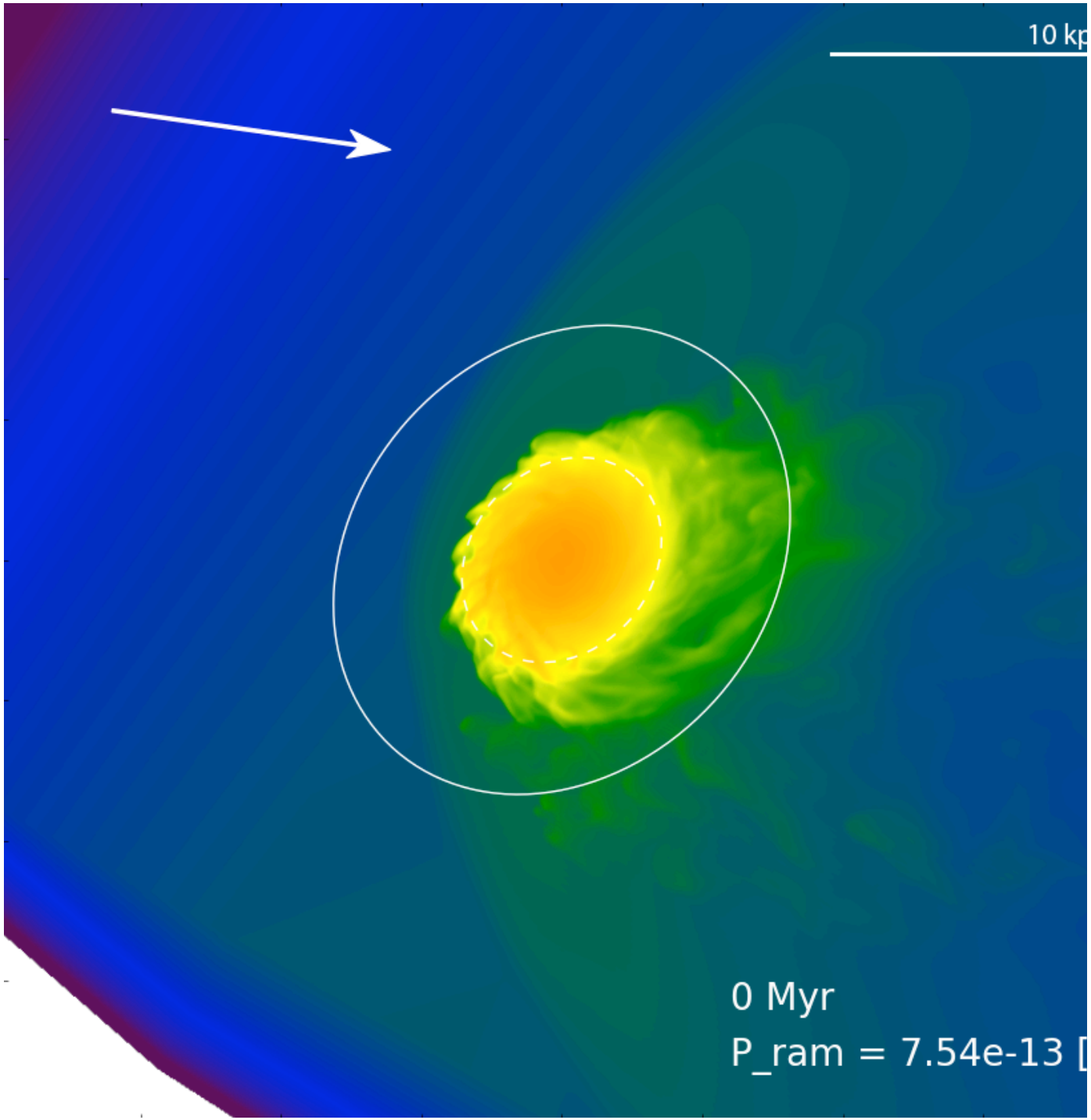
See also: Balbinot et al. 2015; Saha et al. 2010

Salem, Besla et al. 2015

1% of Stream mass is removed …

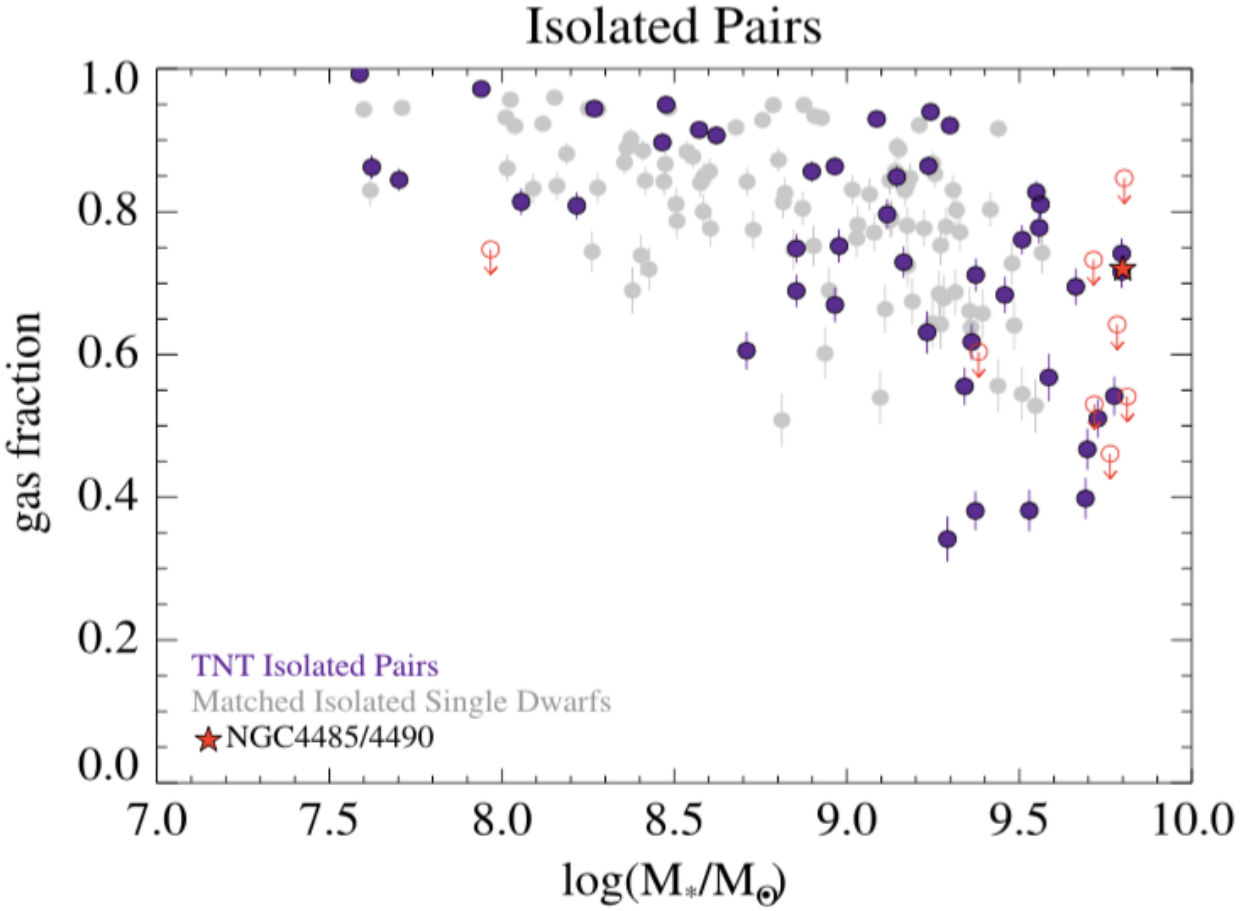
Efficiency of ram pressure depends on the orbit and mass of the satellite

Enzo, AMR Simulations



2. Dwarf-Dwarf Interactions?

Dwarf pairs are gas rich, despite elevated SFRs

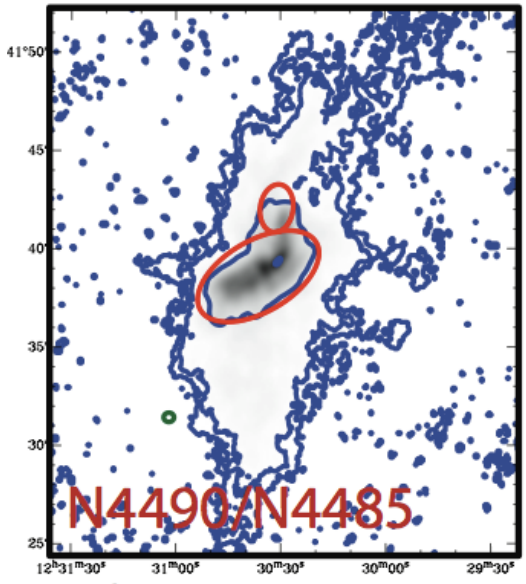


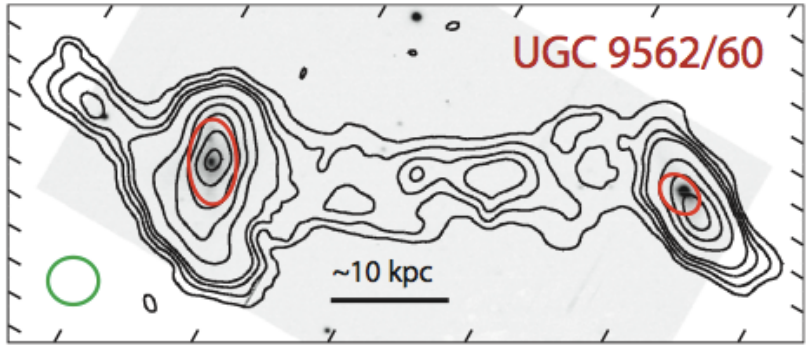
Single Dish
Not Resolved

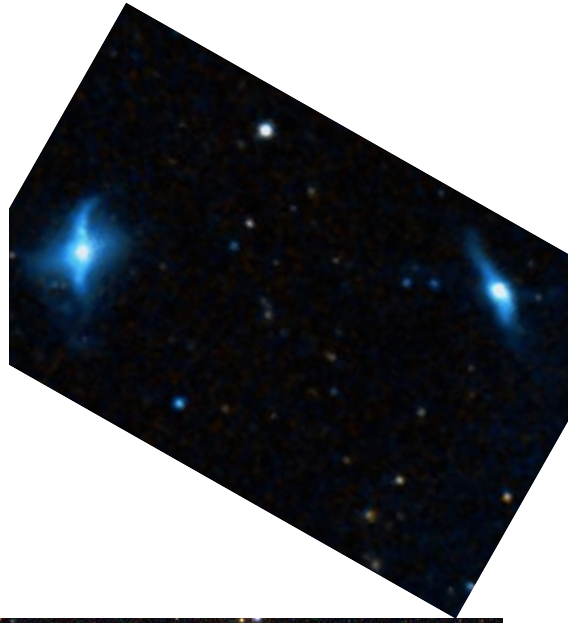
TNT Survey: Stierwalt, GB+2015

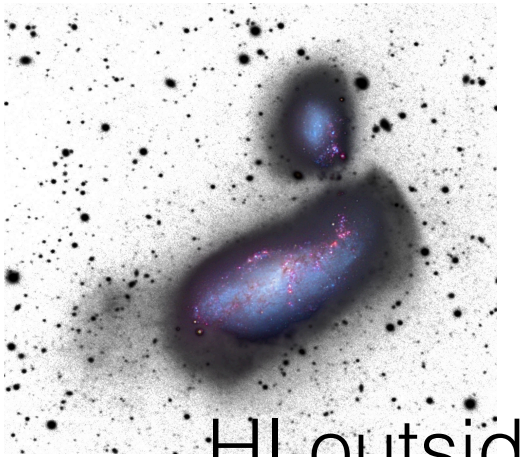
TiNy Titans Local Volume Survey

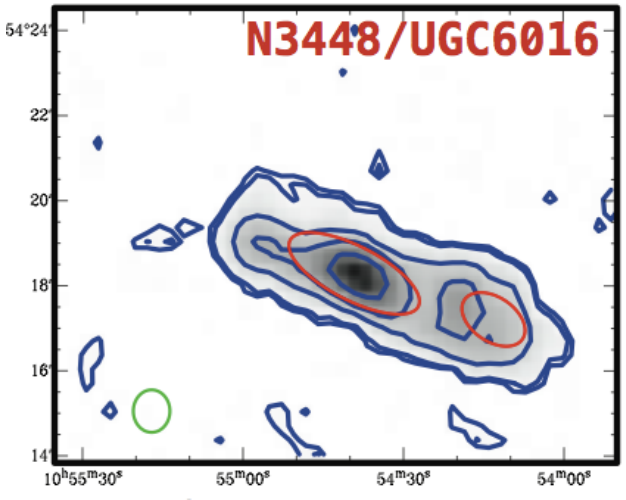
Pearson, Besla, Putman+2016

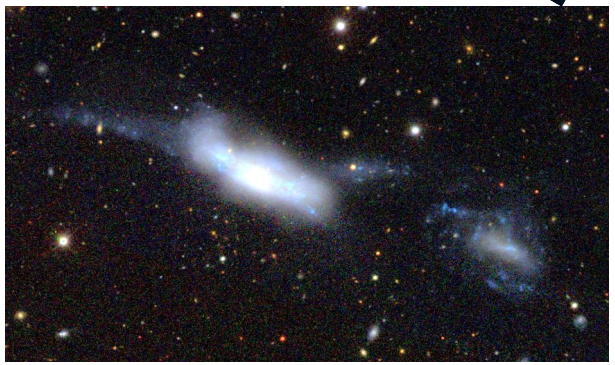








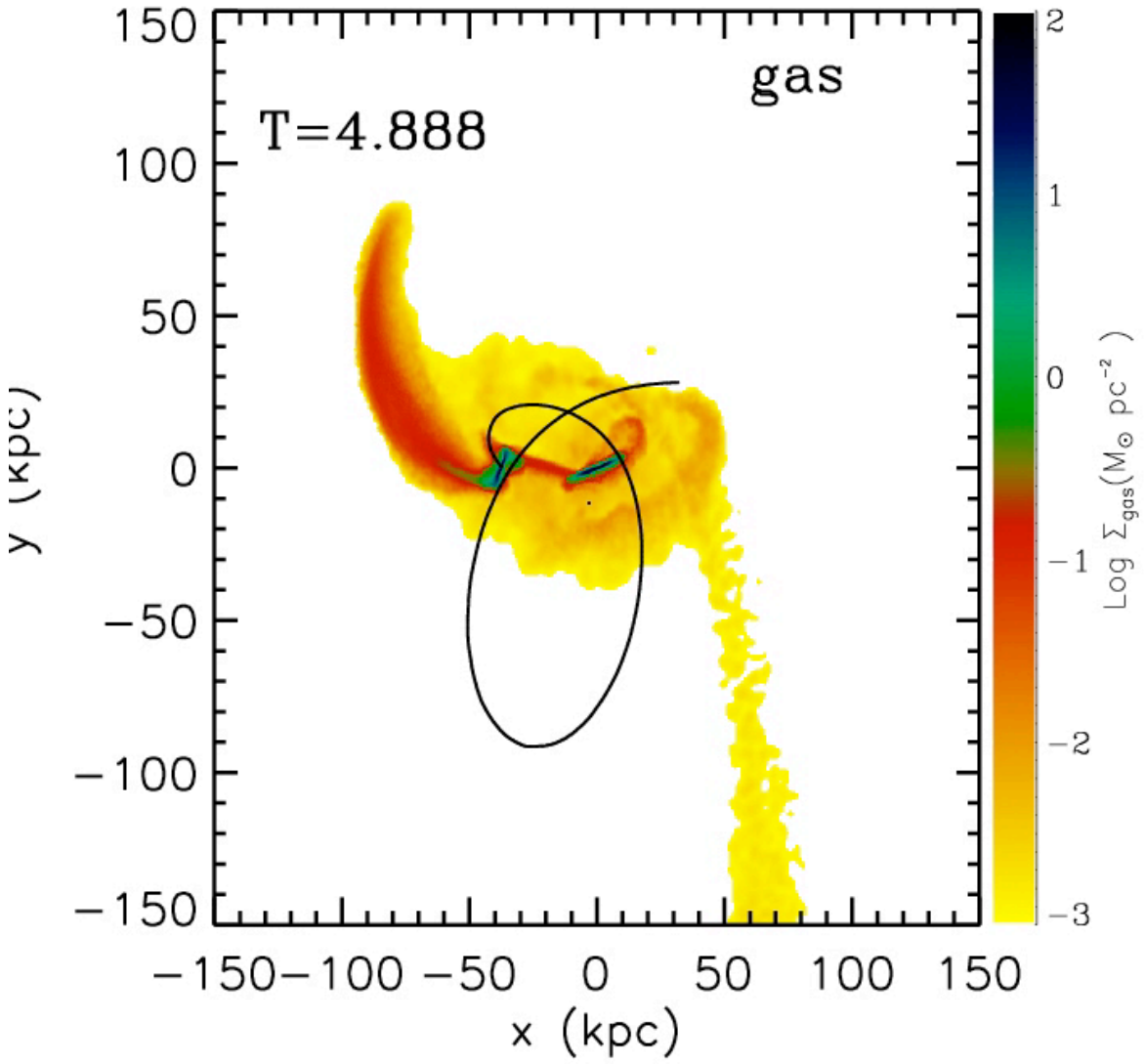




HI outside the main bodies: 20-60% of total

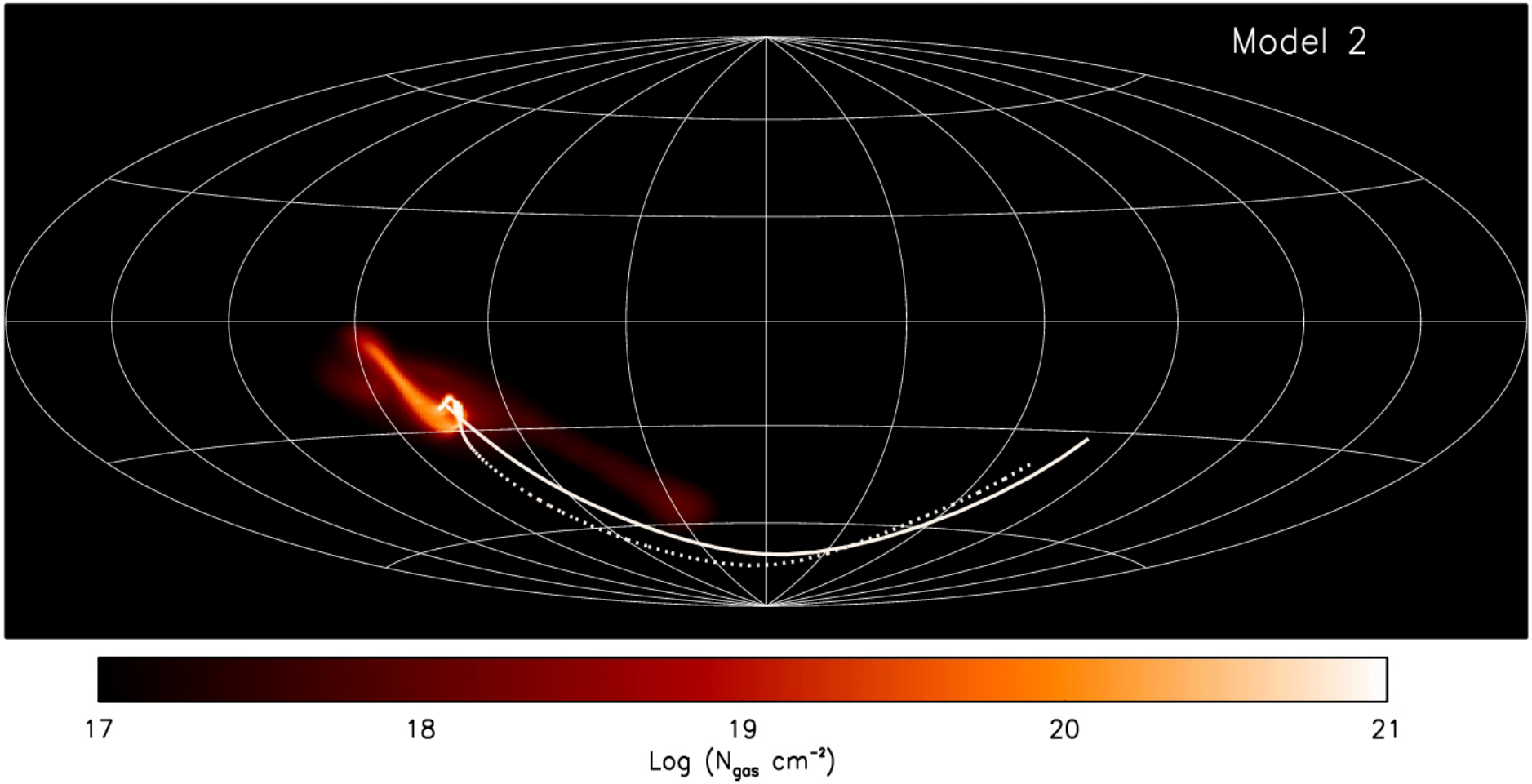
The SMC - LMC Interactions Before Capture by the Milky Way

Gas is stripped but remains bound to the *primary*



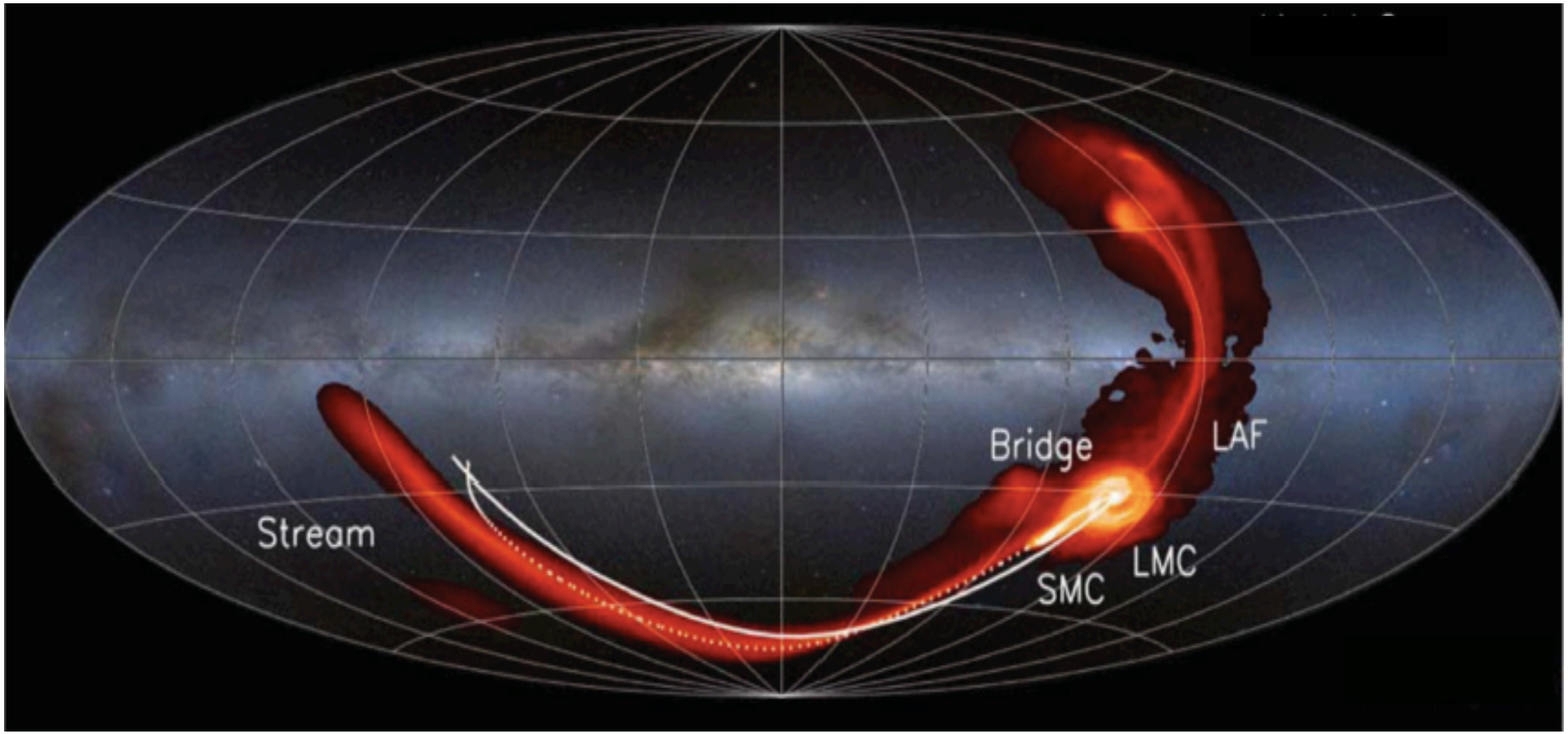
The Formation of the Magellanic Stream

(after capture)



Besla + 2010, 2012

LMC/SMC interactions form the Magellanic Stream, Leading Arm and Bridge

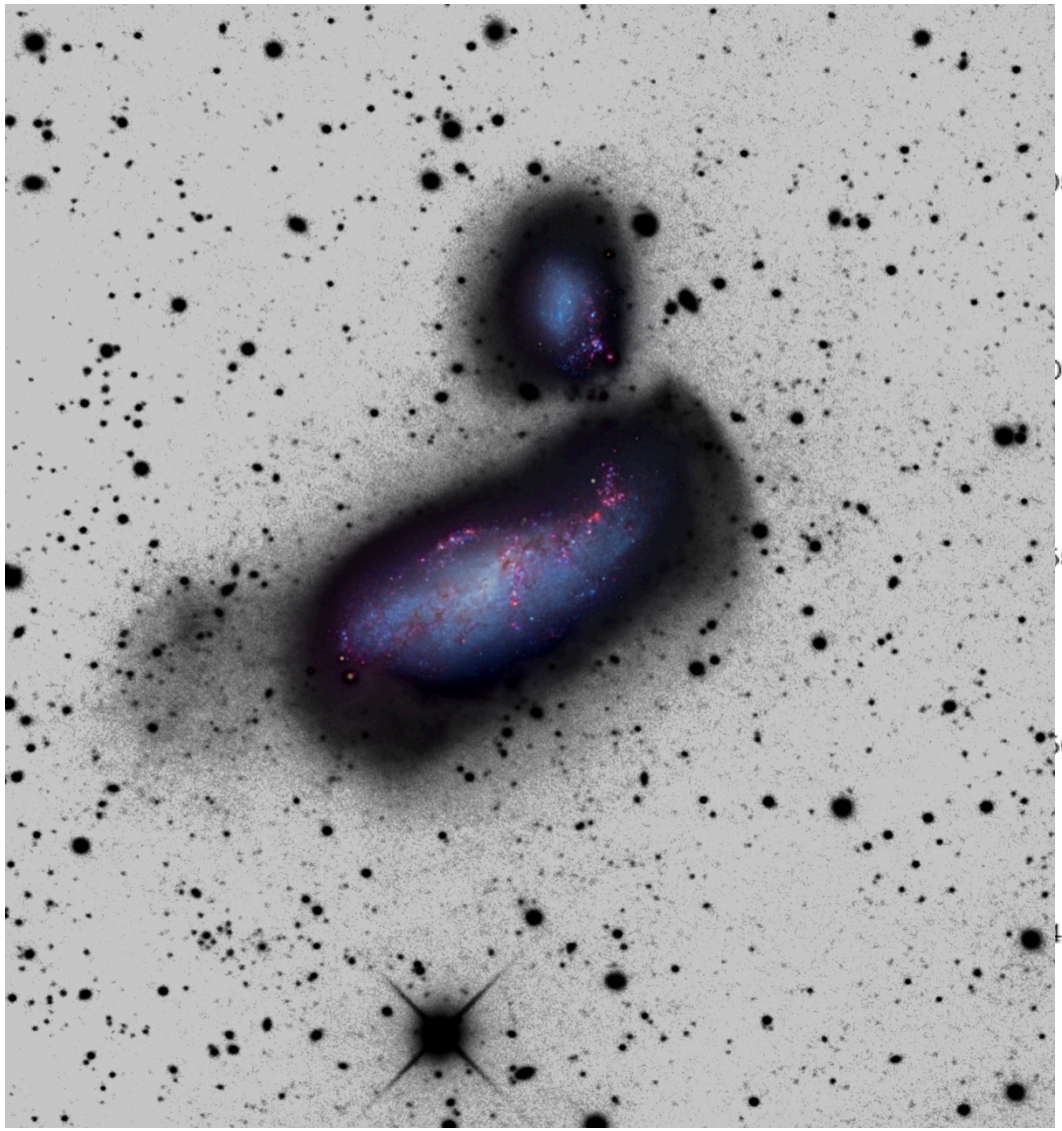


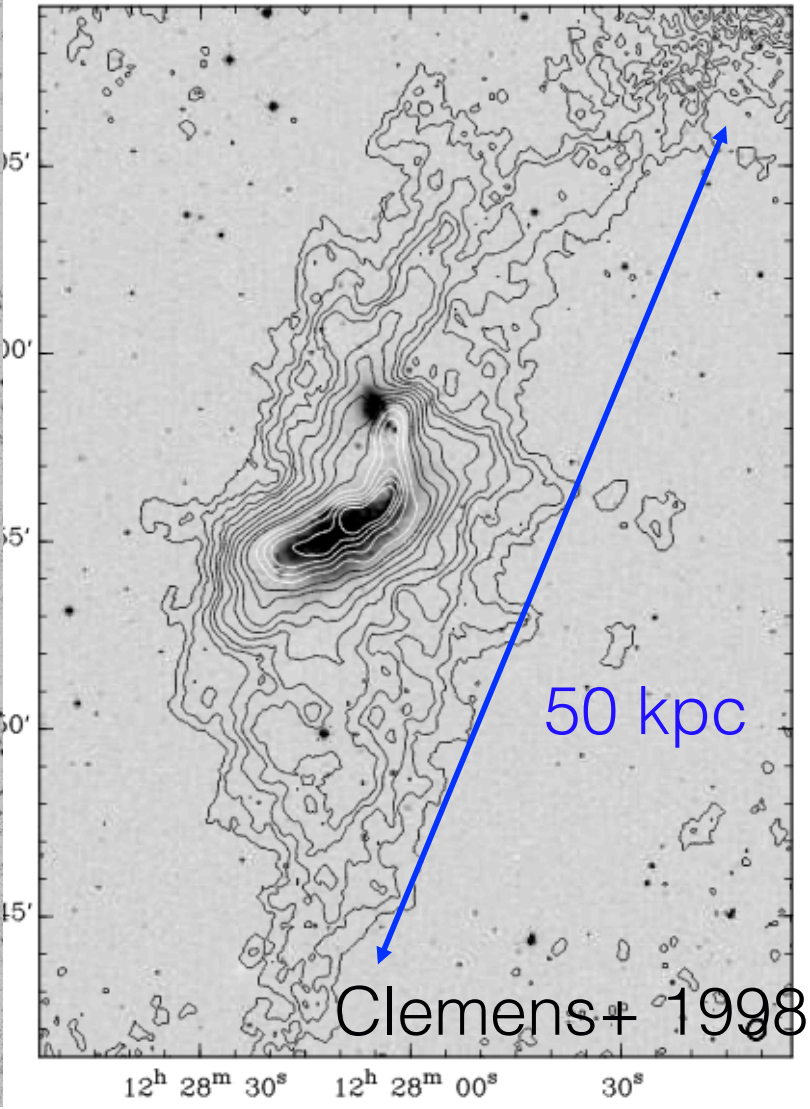
Besla+2012, 2010

EAGLE: Satellite-satellite encounters are found to dominate gas Removal from dwarfs with stellar mass > 10^9 M (Marasco+2016)

Modeling Dwarf-Dwarf Interactions: NGC 4485/90

Sarah Pearson, George Privon, GB



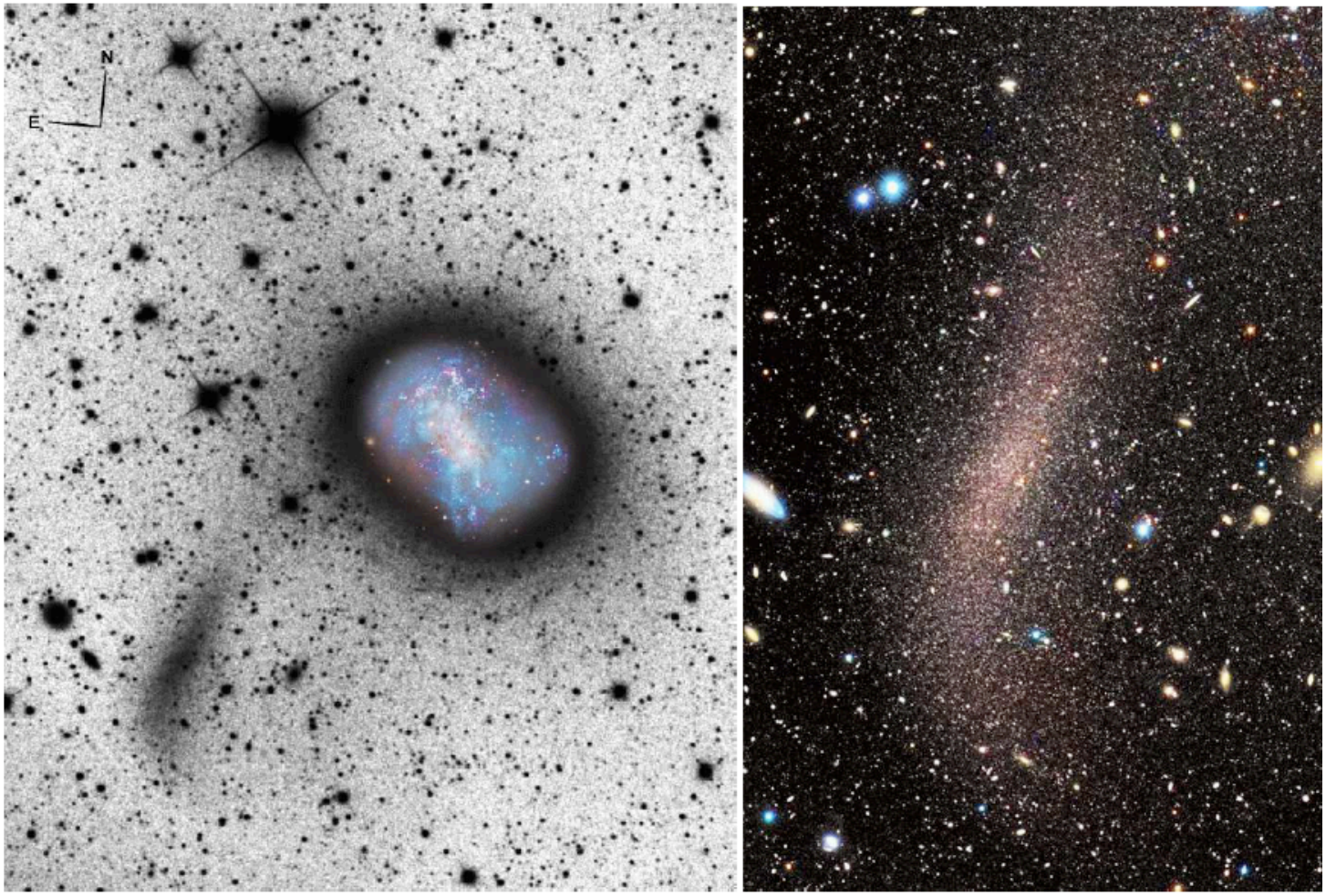


Gabany, Martinez-Delgado

Massive Dwarfs as Hosts: NGC 4449

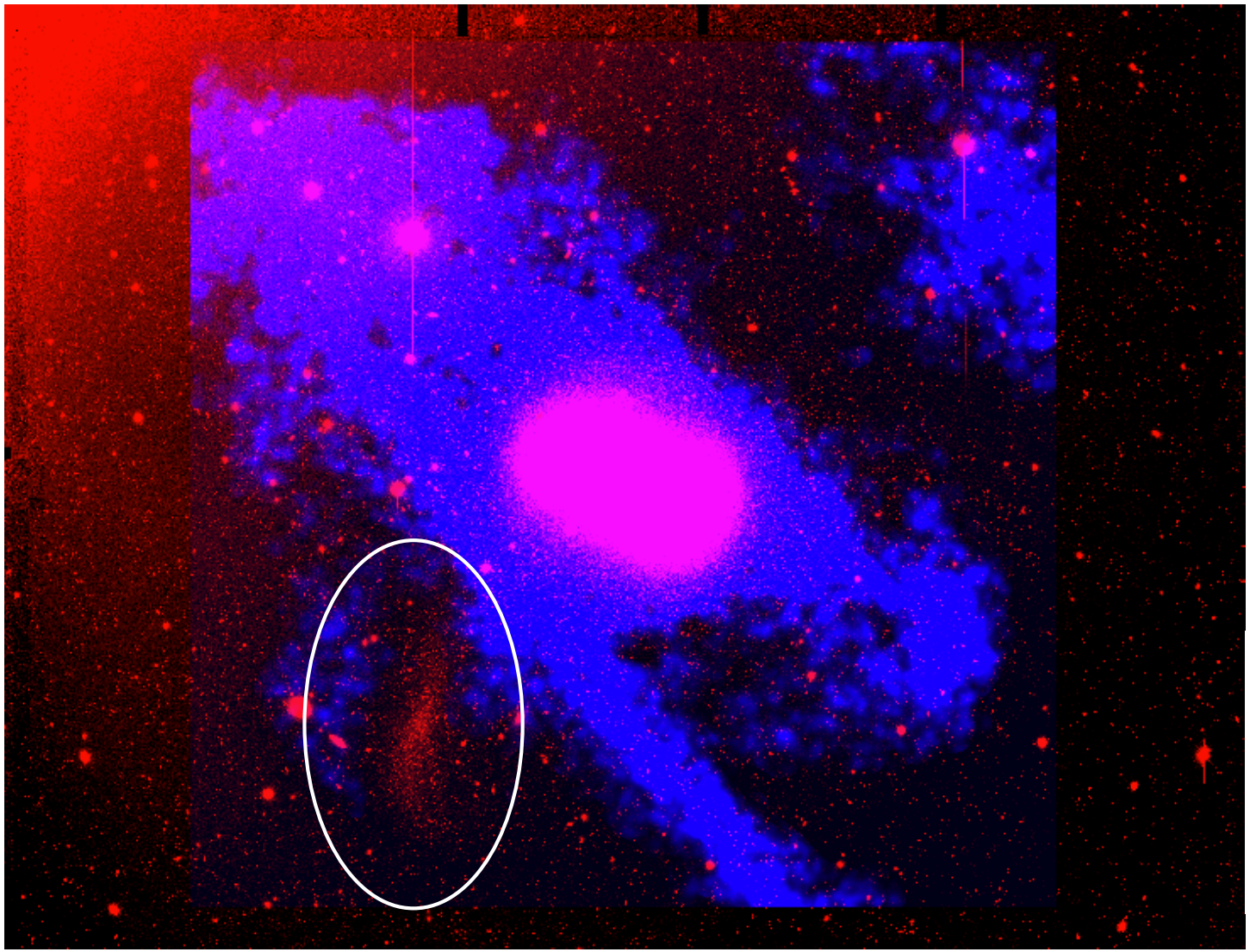
Martinez-Delgado et al. 2011; Rich et al. 2011

1:50 stellar mass ratio



~ 50% of dwarfs presently about the MW are cosmologically expected to have been in a low mass group (Wetzel+2015)

Formation of a gas poor dSph about a Massive Dwarf Host



Hunter 1998 HI data plotted over Subaru data

Courtesy F. Annibaldi

If column density < 10^{19} /cm^2 then M_{gas}/M_{star} < 10%

conclusions

Dwarf galaxies are typically gas rich and star forming. Gas consumption is inefficient, they will not become quenched (gas poor & non-star forming) on their own.

Quenching in dwarfs is governed by proximity to a massive host (cluster, Milky Way type galaxy, OR a massive dwarf) through tides, ram pressure stripping and starvation (not outflows, mergers , starbursts, AGN). Timescale depends on mass & orbit (Wetzel).

Preprocessing in low mass groups (prior to capture) can facilitate quenching and morphological change.

Dwarf-dwarf interactions can remove gas to large distances, greatly aiding gas removal after capture and facilitating gas supply to more massive galaxies (e.g., the Magellanic Stream).